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## A PRELIMINARY STUDY OF THE RANGE OF VISUAL APPREHENSION

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Writers of psychological textbooks usually state that from four to six objects may be apprehended in a single grasp of attention.<sup>1</sup> It is not often that the range of attention is supposed to be greater than six, although a recent text states: "Under ordinary conditions from 6 to 8 objects are clearly distinguished simultaneously. The number may be increased with practice to about 15."<sup>2</sup> The emphasis upon the number six is derived from the pre-experimental work of Sir William Hamilton and his predecessors, but the later experiments seem not to have altered it.<sup>3</sup>

When one examines these measures of the so-called range of attention, however, one finds that the concepts are neither clear nor exact. The usual textbook statement would lead one to believe that all groups up to, say, 4, 5 or 6 objects are invariably capable of being apprehended correctly and that there is no way of assuring correct apprehension of a greater number. Nothing could be further from the case. Take Jevons' early results.<sup>4</sup> He threw at random a few beans

<sup>1</sup> E. B. Titchener, *A Beginner's Psychology*, 1915, 103; J. R. Angell, *Psychology*, 1904, 81; C. S. Myers, *A Text-book of Experimental Psychology*, 1911, 321; W. B. Pillsbury, *The Fundamentals of Psychology*, 1916, 247; R. M. Yerkes, *Introduction to Psychology*, 1911, 297.

<sup>2</sup> H. C. Warren, *Human Psychology*, 1919, 251.

<sup>3</sup> Sir W. Hamilton, *Lectures on Logic and Metaphysics*, 1859-60, I, 253 f. For a survey of the experimental work cf. J. McK. Cattell, *The Inertia of the Eye and Brain*, VIII, 1886, 248-404; B. Erdmann & R. Dodge, *Psychologische Untersuchungen über das Lesen*, 1898; G. M. Whipple, The Effect of Practice Upon the Range of Visual Attention and of Visual Apprehension, *Jour. of Ed. Psychol.*, I, 1910, 249-262; F. N. Freeman, Untersuchungen über den Aufmerksamkeitsumfang und die Zahlauffassung bei Kindern und Erwachsenen, *Päd. Psychol. Arbeit.*, 1910, 88-168; J. Zeitler, Tachistoskopis. Versuche über das Lesen, *Philos. Stud.*, XVI, 1900, 380-463.

<sup>4</sup> W. S. Jevons, The Power of Numerical Discrimination, *Nature*, III, 1871, 281 f. It will be noted that Jevons' results are very incompletely quoted by W. James, *The Principles of Psychology*, 1890, I, 406. James quotes only the results for the first four stimuli, namely, 3, 4, 5, and 6, while Jevons used stimuli up to 15 beans. The results as quoted by James are misleading.

into a box and sought at a glance to estimate their number. His results, thrown into the form of relative frequencies, are as follows:

Number of Beans	Per Cent. Correct Judgment
3	100
4	100
5	96
6	82
7	73
8	56
9	62
10	43
11	38
12	42
13	23
14	28
15	18

Jevons uses as the measure of the discrimination 100 *per cent* correct judgments and concludes that his limit is between 4 and 5 beans.

Cattell's experiments in the Wundtian laboratory yield the following results.

#### PER CENT. CORRECT JUDGMENT

Number of Objects Exposed	Lines	Digits	Letters	Short Words
2				60
3		90	87	23
4	90	74	63	
5	75	60	36	
6	75	34	23	

But here one cannot accurately use 100 *per cent* correct judgments as the measure of apprehension, because the experiments do not include those small values of the stimulus that would give the highest frequencies. One might extrapolate the function to 100 *per cent* if the frequencies indicated the exact nature of the curve.

In view of these facts, it appears that the statistical limen or threshold, used in the work on sensation and perception, is a more reliable and more readily determined measure of the so-called range of attention. The threshold is defined as that value of stimulus the sensing of which has a probability of 0.5; or that value of stimulus which is as likely to be sensed as not. The problem of the range of apprehension presents, statistically, the same problem as does the terminal limen for sensation. In the case of sensation, one is interested in determining, let us say, the value in wave-frequency of the tone

which is sensed just half of the time and which is so high that it is just not sensed half of the time. Similarly, in the range of apprehension, one is interested in determining the number of objects, the correct apprehension of which has a probability of 0.5. The use of the psychophysical procedure in this case not only yields a measure of the range of apprehension that has a maximum degree of precision, but also ordinarily provides a measure of the degree of precision. It is curious that investigators, working outside the field of sensation, have not oftener used the tools of psychophysics that have been so highly developed for sensation. Williams<sup>5</sup> made such an application when he calculated an associative limen by means of the method of constant stimuli, but the extension is unusual.

Jevons' results, although they involve three inversions, can nevertheless, for purposes of rough comparison, be treated by the method of constant stimuli. For his data the limen is 10.28 beans and the coefficient of precision is 0.143,—a statement that is much more definite than Jevons' conclusion: "The limit of complete accuracy, if there were one, would be neither 4 nor 5, but half-way between them; but this is a result as puzzling as one of the uninterpretable symbols in mathematics, just, for instance, like the factorial of a factorial number. But I give it for what it may be worth."<sup>6</sup>

It must be remembered that this threshold will ordinarily be expressed in fractions of an object, even though it is not possible to prepare a fractional number of objects, of which the correct apprehension has a probability of 0.5. The limen is a *statistical limen*, a calculated quantity which summarizes observed results for purposes of scientific comparison. When one finds the upper threshold of tone to be, say, 18,264 *vs.*, one does not seek to construct a stimulus for this frequency in order to see whether it will give 50 *per cent* positive judgments. One is satisfied with the computed limen as part of a statistical account of observations already made.

The present paper presents some preliminary determinations of a limen of visual apprehension.<sup>7</sup> The stimuli were circular dots, 5 mm. in diameter. Four to twelve dots were arranged on cardboards in a haphazard order. Each group fell entirely within the range of foveal vision. These cards were exposed

<sup>5</sup> H. D. Williams, On the Calculation of an Associative Limen, *Amer. Jour. of Psychol.*, XXIX, 1918, 219-226.

<sup>6</sup> Jevons, *op. cit.*

<sup>7</sup> These experiments were performed in the Laboratory of Experimental Psychology at Clark University during the spring of 1920.

by means of a Whipple tachistoscope.<sup>8</sup> A pre-exposure fixation point was used. The subject was seated at a distance of 2.5 m. from the apparatus.

Three series of stimuli were employed. They were:

Series I. Black dots on white background with an exposure time of 100 sigma.

Series II. Black dots on a medium-grey background with an exposure time of 100 sigma.

Series III. Black dots on a white background with an exposure time of 60 sigma.

By comparing Series I and III we hoped to study the effects of the speed of exposure. By comparing the results of Series I and II we hoped to study the effect of the brightness of the stimulus.

Five subjects were employed. They were L. D. Boring, Ph. D. (Ob. B), C. C. Pratt, A. M. (Ob. P), S. Yokoyama, A. M. (Ob. Y), M. Bates, A. M. (Ob. Ba) and J. H. Alston, A. M. (Ob. A). The instructions were: "You will be shown successively, for a very short exposure, cards which will contain a varying number of black dots on a white (or grey) background. Immediately after the exposure you will report verbally the number of dots which you have apprehended. Be sure of your judgment and do not guess. The report 'I do not know' is admitted."

The judgments were recorded either as 'correct' or 'not correct.' Seven cards were shown in each series, four to ten dots to Obs. P, Ba and A; six to twelve dots to Obs. B and Y. Nine series of cards were prepared (63 cards in all); each series was shown an equal number of times; and the cards of each series were shuffled after the series had been presented. In Series I (white background, 100 sigma exposure) 250 judgments for each number of dots were obtained from each subject. In Series II (grey background, 100 sigma exposure) 150 judgments were obtained, and in Series III (white background, 60 sigma exposure) 150 judgments were obtained from each subject. The results were fractionated into groups of 50 judgments on each stimulus and each fraction was treated separately by Urban's procedure for the method of constant stimuli.<sup>9</sup>

<sup>8</sup> For a description of this apparatus cf. G. M. Whipple, *Manual of Mental and Physical Tests*, I, 1914, 264 f.

<sup>9</sup> For a description of this form of mathematical treatment cf. F. M. Urban, *Hilfstabellen für die Konstanzmethode*, *Arch. f. d. ges. Psychol.*, XXIV, 1912, 236-243.

TABLE I

OB. B.								
Fractions		Number of Dots						
		6	7	8	9	10	11	12
Series I	I	0.96	0.88	0.72	0.58	0.44		
	II	1.00	0.96	0.88	0.52	0.46	0.28	0.12
	III	1.00	0.96	0.84	0.64	0.46	0.28	0.20
	IV	1.00	0.96	0.74	0.58	0.44	0.22	0.22
	V	1.00	0.98	0.84	0.56	0.36	0.18	0.10
	Ave.	0.99	0.95	0.80	0.58	0.43	0.24	0.16
Series II	VI	1.00	0.98	0.86	0.56	0.34	0.22	0.08
	VII	1.00	0.98	0.90	0.60	0.38	0.20	0.10
	VIII	1.00	0.98	0.90	0.74	0.54	0.30	0.12
	Ave.	1.00	0.98	0.89	0.63	0.42	0.24	0.10
Series III	IX	1.00	0.98	0.92	0.74	0.46	0.32	0.16
	X	1.00	1.00	0.92	0.86	0.56	0.32	0.22
	XI	1.00	0.98	0.94	0.74	0.52	0.28	0.18
	Ave.	1.00	0.99	0.93	0.78	0.51	0.31	0.19

TABLE II

OB. P.								
Fractions		Number of Dots						
		4	5	6	7	8	9	10
Series I	I	1.00	0.92	0.84	0.60	0.06	0.00	0.00
	II	1.00	0.98	0.88	0.60	0.04	0.00	0.00
	III	1.00	0.98	0.92	0.48	0.08	0.00	0.00
	IV	0.96	0.88	0.82	0.56	0.08	0.00	0.02
	V	0.96	0.94	0.90	0.64	0.20	0.00	0.00
	Ave.	0.98	0.94	0.87	0.58	0.09	0.00	0.00
Series II	VI	1.00	0.98	0.86	0.62	0.30	0.00	0.00
	VII	0.98	0.96	0.80	0.56	0.06	0.02	0.00
	VIII	0.98	0.94	0.78	0.48	0.16	0.02	0.00
	Ave.	0.99	0.96	0.81	0.55	0.17	0.01	0.00
Series III	IX	0.98	0.96	0.80	0.58	0.24	0.04	0.00
	X	1.00	0.96	0.88	0.68	0.30	0.06	0.00
	XI	1.00	0.96	0.92	0.62	0.28	0.04	0.00
	Ave.	0.99	0.96	0.87	0.63	0.27	0.05	0.00

TABLE III

OB. Y.								
Fractions		Number of Dots						
		6	7	8	9	10	11	12
Series I	I	0.98	0.94	0.86	0.72	0.54		
	II	0.98	0.94	0.90	0.68	0.64	0.42	0.20
	III	1.00	0.98	0.92	0.72	0.56	0.44	0.16
	IV	1.00	0.98	0.92	0.80	0.70	0.50	0.30
	V	1.00	1.00	0.98	0.90	0.72	0.56	0.30
	Ave.	0.99	0.97	0.92	0.76	0.63	0.48	0.24
Series II	VI	1.00	0.98	0.96	0.88	0.74	0.56	0.34
	VII	1.00	0.98	0.94	0.92	0.82	0.54	0.42
	VIII	1.00	0.98	0.94	0.86	0.68	0.48	0.28
	Ave.	1.00	0.98	0.95	0.89	0.75	0.53	0.35
Series III	IX	1.00	0.98	0.92	0.88	0.72	0.48	0.24
	X	1.00	0.98	0.92	0.88	0.78	0.54	0.28
	XI	1.00	0.98	0.96	0.88	0.74	0.56	0.34
	Ave.	1.00	0.98	0.93	0.88	0.75	0.53	0.29

TABLE IV

OB. BA.								
Fractions		Number of Dots						
		4	5	6	7	8	9	10
Series I	I	0.98	0.96	0.90	0.74	0.14	0.00	0.00
	II	1.00	0.96	0.96	0.64	0.12	0.04	0.00
	III	1.00	0.98	0.88	0.68	0.24	0.02	0.00
	IV	1.00	0.96	0.92	0.70	0.22	0.02	0.00
	V	1.00	0.96	0.90	0.72	0.40	0.16	0.02
	Ave.	1.00	0.96	0.91	0.70	0.22	0.05	0.00
Series II	VI	1.00	0.98	0.94	0.76	0.48	0.22	0.02
	VII	1.00	0.98	0.92	0.76	0.46	0.22	0.06
	VIII	1.00	0.98	0.94	0.72	0.48	0.24	0.06
	Ave.	1.00	0.98	0.93	0.75	0.47	0.23	0.05
Series III	IX	1.00	0.96	0.88	0.76	0.42	0.24	0.06
	X	1.00	0.98	0.92	0.74	0.24	0.12	0.04
	XI	1.00	0.98	0.94	0.78	0.38	0.18	0.06
	Ave.	1.00	0.97	0.91	0.76	0.35	0.18	0.05

TABLE V

OB. A.								
Fractions		Number of Dots						
		4	5	6	7	8	9	10
Series I	I	0.68	0.52	0.38	0.22	0.20	0.16	0.10
	II	0.88	0.72	0.50	0.36	0.30	0.16	0.10
	III	0.96	0.88	0.72	0.36	0.34	0.24	0.22
	IV	0.96	0.94	0.68	0.56	0.44	0.24	0.22
	V	1.00	0.94	0.82	0.60	0.42	0.24	0.20
	Ave.	0.90	0.80	0.62	0.42	0.34	0.21	0.17
Series II	VI	1.00	0.98	0.84	0.56	0.36	0.26	0.22
	VII	0.96	0.90	0.78	0.62	0.44	0.28	0.22
	VIII	0.98	0.94	0.80	0.64	0.38	0.20	0.16
	Ave.	0.98	0.94	0.81	0.61	0.39	0.25	0.20
Series III	IX	0.98	0.92	0.78	0.64	0.42	0.26	0.18
	X	1.00	0.98	0.92	0.76	0.56	0.28	0.20
	XI	1.00	0.96	0.92	0.72	0.48	0.28	0.18
	Ave.	0.99	0.95	0.87	0.71	0.49	0.27	0.19

The observed relative frequencies of correct judgments are to be found in Tables I-V, which give for each observer and for every fraction of 50 judgments the relative frequency of correct judgments on every number of dots employed. The averages for each series are averages of the fractions of that series. An examination of these tables shows that we are here dealing with a continuous function. In the case of every group for every observer, the relative frequencies of correct judgments are high for the low values of stimulus and decrease regularly as the number of dots increases. There is not a single inversion in the entire five tables.

These relations become more obvious when the results are thrown into the form of curves. Figure I gives these curves for Ob. Ba. The average relative frequencies (Table IV) of the three series are plotted. The curves resemble the *phi-gamma function*, but are asymmetrical in that the dispersion of the supraliminal portion is less than that of the subliminal part.

The numerical values of the thresholds (S) and of the coefficients of precision (h) are given in Tables VI-X. It will be observed that both the values of the observed relative

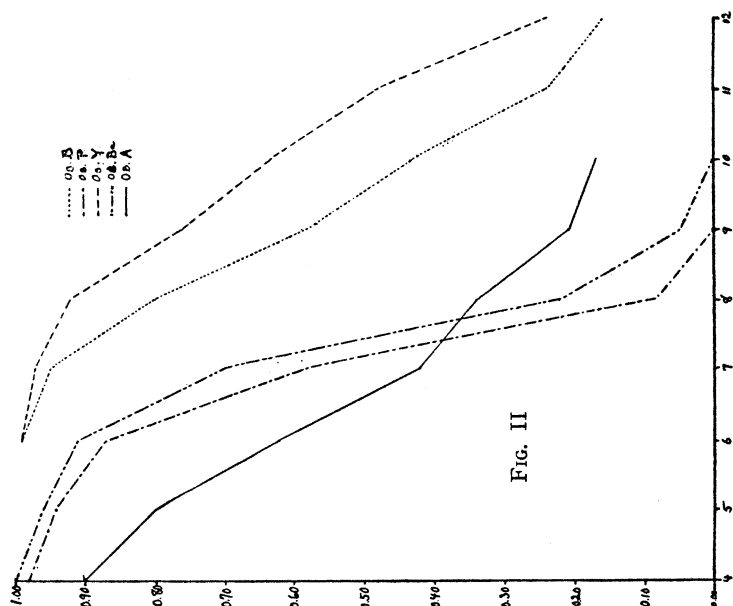
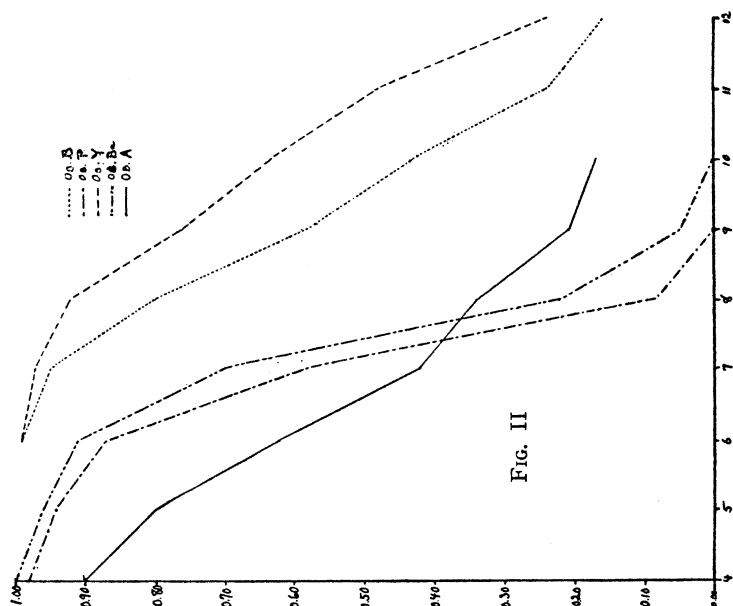


TABLE VI

OB. B.						
Fractions	Series I		Series II		Series III	
	h	S	h	S	h	S
I	0.314	9.499	0.441	9.554	0.421	10.140
II	0.385	9.755	0.454	9.683	0.416	10.442
III	0.349	9.969	0.434	10.122	0.429	10.204
IV	0.312	9.695				
V	0.450	9.551				
Ave.	0.362	9.694	0.443	9.786	0.422	10.262

TABLE VII

OB. P.						
Fractions	Series I		Series II		Series III	
	h	S	h	S	h	S
I	0.642	6.939	0.586	7.359	0.555	7.097
II	0.862	6.996	0.644	6.864	0.595	7.376
III	0.880	6.942	0.590	6.848	0.640	7.305
IV	0.501	6.883				
V	0.492	7.246				
Ave.	0.675	7.001	0.607	7.024	0.597	7.259

frequencies and those of the coefficients of precision and the thresholds are relatively similar for the different series for each observer. It was expected that the form of the curves might vary for the different series, thus showing the influence of the brightness of the backgrounds and of the length of the exposure times. No such variation is present for any subject.

Probably the effect of practice obscures any slight differences that might otherwise occur between the series. Practice is evident in the higher values of both the threshold and the coefficient of precision. The effect of practice upon the

TABLE VIII

OB. Y.						
Fractions	Series I		Series II		Series III	
	h	S	h	S	h	S
I	0.345	10.204	0.365	11.252	0.390	10.884
II	0.331	10.334	0.342	11.535	0.365	11.126
III	0.389	10.374	0.381	10.912	0.365	11.252
IV	0.341	10.954				
V	0.425	11.138				
Ave.	0.366	10.601	0.362	11.233	0.373	11.087

TABLE IX

OB. BA.						
Fractions	Series I		Series II		Series III	
	h	S	h	S	h	S
I	0.581	7.282	0.556	7.906	0.469	7.830
II	0.700	7.146	0.518	7.909	0.592	7.565
III	0.700	7.289	0.509	7.934	0.553	7.835
IV	0.687	7.294				
V	0.532	7.650				
Ave.	0.640	7.332	0.527	7.916	0.538	7.743

coefficient of precision is noticeable when the average values of every subject, except Ob. P, are compared. The effect on the thresholds is marked for all subjects, especially for Ob. A. These results accord with former experiments on the effects of practice upon visual apprehension.<sup>10</sup>

<sup>10</sup> G. M. Whipple, The Effect of Practice Upon the Range of Visual Attention and of Visual Apprehension, *Jour. of Ed. Psychol.*, I, 1910, 249-262; K. M. Dallenbach, The Effect of Practice Upon Visual Apprehension in School Children, *Jour. of Ed. Psychol.*, V, 1914, 321-334, 387-404; K. M. Dallenbach, The Effect of Practice Upon Visual Apprehension in the Feeble-Minded, *Jour. of Ed. Psychol.*, X, 1919, 61-82; cf. *Journ. Exp. Psych.*, iii, 1920, 228 f.

TABLE X

OB. A.						
Fractions	Series I		Series II		Series III	
	h	S	h	S	h	S
I	0.204	4.974	0.336	7.757	0.338	7.768
II	0.276	6.435	0.303	7.825	0.413	8.276
III	0.290	7.291	0.373	7.660	0.400	8.102
IV	0.299	7.632				
V	0.339	7.776				
Ave.	0.282	6.822	0.337	7.747	0.384	8.049

Figure II gives a comparison of the results for the different observers. The psychometric functions for each subject in Series I are plotted together. The graphs illustrate the relative positions of the thresholds for the five observers. Ob. Y has the highest values, ranging for all of the three series about 11 dots. Next lower are the values for Ob. B, ranging about 10 dots. The values for Ob. Ba are about 7 to 8 dots; those for Ob. A in the neighborhood of 7 to 8 dots; and those for Ob. P are the lowest, being very close to 7 dots.

It seemed also of interest to determine just what were the mental processes underlying the formation of these judgments of visual apprehension. For this purpose, some introspections were obtained from each of the subjects. An analysis of these introspections reveals the following facts.

For Ob. B, the process was essentially one of utilizing the immediate memory after-image after the exposure was completed and of grouping the dots for purposes of apprehension. This grouping was present even for the lower values of stimulus (6 and 7 dots for this subject). The following introspection is typical for this observer:

"This time the judgment came very quickly and was accompanied by an attitude of great subjective certainty. The spot-pattern was very distinct and the dots were very uniformly black and very sharply outlined. After the exposure, there was a visual memory after-image left for a moment after the light had streaked by. The counting in vocal-motor terms began while this was still present. The left part of this image was most distinct and was counted first. Fixation, with accompanying kinaesthesia of effort, of the exposure square persisted until the counting was finished. The counting was in groups with eye-movements from the location of one group to that of the next as I counted."

The process for Ob. P were very rapid and the judgment was reported as having been formed during the time of the actual exposure. Eye-movement did not seem to be present but, even though the exposures were as short as 100 and 60 sigma, there was grouping. This grouping was present, apparently, in shifts of clearness and of focality. The following is a typical introspection:

"When the shutter was removed, there was intensive, but indistinct visual perception of a light and rather extended area. This first immediate visual perception was rapidly followed by a standing-out, with respect to clearness, of the central portion of the area. In this central portion, I perceived focally the three dots (which formed the upper portion of the figure). Then there was a rapid shift in focality in which I perceived very clearly the remaining dots of the figure. There was also vocal-motor imagery, very rapid, telescoped and non-focal, present with the changing focality of the dots, of 'four—seven.' This was then vocalized and general relaxation followed."

Ob. Y's processes were very similar to those of Ob. P. The processes were rapid and the judgment was reported as being completed by the end of the exposure-period. Grouping was present, again in terms of shifts of clearness and focality. The following introspection will illustrate the processes employed:

"I had a clear auditory perception of the 'ready' signal, which was followed immediately by the clear perception of the dots arranged in the form of an uneven square. The attention then shifted to the upper right-hand part of the figure. Rapid perception of four dots which stood out very clearly. Then I had a clear perception of three dots in the lower left-hand part of the figure. Then immediately I had a very clear perception of another group of three dots in the central part of the figure. Then followed the verbalization 'ten' which was followed by intensive pleasantness."

Observers Ba and A were not so highly trained in introspection as were the other subjects. Still their protocols give an insight into the processes present. Ob. Ba employed a process very similar to that reported by Ob. B. A visual memory after-image of the stimulus was present immediately after the exposure. Grouping was present in terms of clearness-shifts in this image. The following introspection illustrates the process employed:

"There was first a perception of the stimulus as a whole, no part of it being any clearer than any other part. This was followed by a visual memory after-image which lasted only a very short time. Then a true visual image of the stimulus came in. First the left-hand side was clearest and I had a vocal-motor 'four.' Then the right-hand side became clearer and I had a vocal-motor 'three.' Then the entire image became fairly clear and this was immediately followed by the verbalization of 'seven'."

Observer A employed an immediate visual after-image, and grouping was present in terms of clearness-shifts in this image. The following typical introspection is given:

"Immediately after the exposure I had a visual memory after-image of the stimulus. At first three dots in the upper portion of the figure were very clear. This was followed almost simultaneously by a standing-out clearly of two dots in the lower portion of the figure. Then an image in which all five dots were clear and focal came in rather suddenly and gradually faded out. The judgment was then verbalized."

A consideration of these introspections reveals that grouping was always present for all of the observers. The exposure-times which were employed were too brief to admit eye-movements. Still the splitting up of the total stimulus into groups was accomplished by means of shifts of clearness and of focality. The observers may be divided into two distinct types. For Obs. Y and P this grouping of the dots by means of clearness shifts was reported as being accomplished during the actual exposure of the stimulus, and the judgment was completed by the end of the very brief exposure-time. For Obs. B, Ba and A, this grouping took place in a visual memory after-image which appeared immediately after the exposure was completed. One might hope here to discover a basis for the differences in the size of the limen between the different subjects but, unfortunately, the hope is disappointed. The grouping on the side of process is: Immediate type of judgment, Obs. Y and P; use of visual memory after-image, Obs. B, Ba and A. The grouping of subjects on the basis of limen-values is: Higher values, Obs. B and Y; lower values, Obs. Ba, P and A. The groups in the two cases do not agree. Ob. Y, who employed the immediate type of judgment, had the highest limen-values; while Ob. P, who employed the same type of process, had the lowest.

From a consideration of the introspections we are convinced that the range of attention is an erroneous title for this sort of experiment. We have, therefore, followed Whipple and Dallenbach in calling the problem, in this sort of experiment, the range of visual apprehension.

### *Conclusions*

1. The observed relative frequencies of correct judgments in experiments upon range of visual apprehension follow a continuous function of ogive form
2. The statistical limen, that stimulus-value for which correct judgments are given in 50 *per cent.* of the cases, is the most reliable measure of the range of visual apprehension.
3. In our experiments the individual limens for simultaneous visual apprehension ranged from six to over eleven stimulus objects (dots).